MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2022/2023

EEL 3136 – ELECTRICAL DRIVES

(LE)

07 JULY 2023
9:00 AM to 11:00 AM
(2 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of 9 pages including cover page with 4 Questions only.
2. Answer ALL questions. All questions carry equal marks and the distributions of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

A separately excited DC motor is used for a pressing machine. The copper rod is fed into the presser machine, the motor rotates the presser and transform the rod into plate. The load is constant at 120 Nm. Maximum speed of the machine is 1800 rpm.

a) Calculate the mechanical power for the motor.

[2 marks]

b) State the quadrant in which the motor operates.

[3 marks]

c) Select motor and drives for the machine (refer Tables Q1a and Q1b).

[5 marks]

d) Calculate the firing angle required at DC drives to run the motor at 600 rpm and at half of the load.

[11 marks]

e) Explain why DC drives need to be placed in a cool and dry place.

[4 marks]

Continued...

Table Q1a: DC Motor Selection Motor

135 Nm 132-4M

Technical data

	n_{max}	n_0	J	P_r	U_{smax}	U_r	V_{cool}	Pr	$W_{(foot)}$	$W_{(flange)}$
	4000 min⁻¹	40 min⁻¹	0.12 kgm²	830 W	620 V	110-440 V	470 m³/h	550 Pa	145 kg	160 kg

Cat. Nr	U_a (V):	260	400	420	440	470	520	P	I	T	η	n_2	R_A (115°C)	L_A (0Hz)
FR 156...			n_b (min⁻¹)					(kW)	(A)	(Nm)	(%)	min⁻¹	(Ω)	(mH)
241-AB			730					10.2	35.0	133.0	68.8	1200	2.81	42.0
				780				10.9	35.0	133.0	70.1	1200		
					830			11.6	35.0	133.0	71.3	1200		
						900		12.6	35.0	133.0	72.8	1200		
							1030	14.1	34.4	131.0	75.4	1200		
241-BB		515						7.4	43.0	137.0	61.6	1410	1.88	29.2
			930					13.3	43.0	137.0	73.6	1410		
				985				14.1	43.0	137.0	74.7	1410		
					1045			15.0	43.0	137.0	75.7	1410		
						1130		16.2	43.0	137.0	77.0	1410		
							1285	18.0	42.3	134.0	79.1	1410		
241-CB		605						8.9	49.0	140.0	65.6	1520	1.46	23.6
			1060					15.6	49.0	140.0	76.2	1520		
				1125				16.5	49.0	140.0	77.2	1520		
					1190			17.5	49.0	140.0	78.1	1520		
						1285		18.9	49.0	140.0	79.2	1520		
							1455	21.0	48.2	138.0	81.1	1520		
241-DB		715						9.7	51.0	130.0	69.0	1860	1.22	18.7
			1230					16.7	51.0	130.0	78.5	1860		
				1300				17.7	51.0	130.0	79.3	1860		
					1375			18.6	51.0	130.0	80.1	1860		
						1480		20.1	51.0	130.0	81.1	1860		
							1670	22.3	50.2	127.0	82.8	1860		
241-EB		845						12.2	62.0	138.0	72.2	2050	0.89	14.2
			1430					20.7	62.0	138.0	80.7	2050		
				1510				21.9	62.0	138.0	81.5	2050		
					1595			23.1	62.0	138.0	82.2	2050		
						1720		24.9	62.0	138.0	83.1	2050		
							1935	27.5	61.0	136.0	84.5	2050		
241-FB*		1015						14.0	69.0	132.0	74.8	2500	0.71	10.5
			1700					23.4	69.0	132.0	82.4	2500		
				1795				24.8	69.0	132.0	83.1	2500		
					1895			26.1	69.0	132.0	83.7	2500		
						2040		28.1	69.0	132.0	84.5	2500		
							2290	31.0	67.9	129.0	85.8	2500		
241-GB		1285						15.8	74.0	118.0	78.8	3350	0.52	7.3
			2100					25.8	74.0	118.0	84.9	3350		
				2220				27.3	74.0	117.0	85.5	3350		
					2335			28.7	74.0	117.0	86.0	3350		
						2515		30.8	74.0	117.0	86.6	3350		
							2805	33.9	72.8	115.0	87.6	3350		
241-HB*		1665						22.1	100.0	127.0	82.5	3900	0.03	4.6
			2690					35.7	100.0	127.0	87.4	3900		
				2835				37.6	100.0	127.0	87.8	3900		
					2980			39.6	100.0	127.0	88.2	3900		
						3200		42.5	100.0	127.0	88.7	3900		
							3570	46.5	98.3	125.0	89.5	3900		
231-HB		2280						27.7	122.0	116.0	85.1	4000	0.19	2.6
			3645					44.1	122.0	116.0	88.9	4000		

Continued...

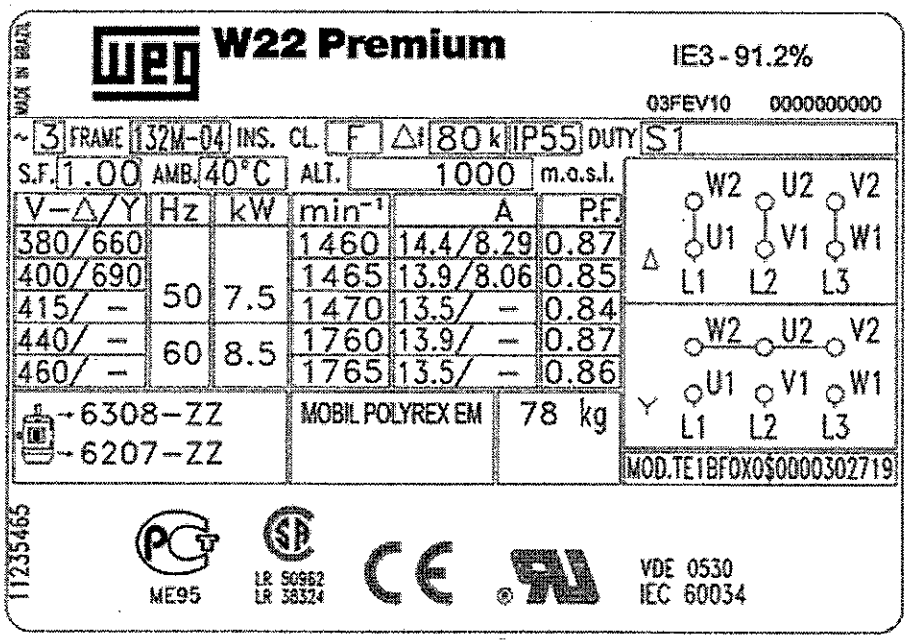
Table Q1b: DC Drives Selection Table

Unit type 2-Q converters	I_{DC} ① [A]	P_{dn} ② 400V [kW]	P_{dn} ② 500V [kW]	Unit type 4-Q converters	I_{DC} ① [A]	P_{dn} ② 400V [kW]	P_{dn} ② 500V [kW]	Int. fwd current [A]	Fan volt. [V,~]	Air volume [m³/h]	P_{vn} [kW]	④	Frame size
400 V / 500 V / 525 V		400V	500V			400V	500V						
DCS800-S01-0020-04/05	20	9	12	DCS800-S02-0025-04/05	25	10	13	6	without fan	300	0.11		D1
DCS800-S01-0045-04/05	45	21	25	DCS800-S02-0050-04/05	50	21	26	6		300	0.17		D1
DCS800-S01-0065-04/05	65	30	36	DCS800-S02-0075-04/05	75	31	39	6		300	0.22		D1
DCS800-S01-0090-04/05	90	42	52	DCS800-S02-0100-04/05	100	42	52	6		300	0.28		D1
DCS800-S01-0125-04/05	125	58	73	DCS800-S02-0140-04/05	140	58	73	6		300	0.38		D1
DCS800-S01-0180-04/05	180	84	104	DCS800-S02-0200-04/05	200	83	104	15	115/230; 1-ph	300	0.55		D2
DCS800-S01-0230-04/05	230	107	133	DCS800-S02-0260-04/05	260	108	135	15		300	0.73		D2
DCS800-S01-0315-04/05	315	146	183	DCS800-S02-0350-04/05	350	145	182	20		600	0.91		D3
DCS800-S01-0405-04/05	405	188	235	DCS800-S02-0450-04/05	450	187	234	20		600	1.12		D3
DCS800-S01-0470-04/05	470	218	280	DCS800-S02-0520-04/05	520	216	276	20		600	1.32		D3
DCS800-S01-0610-04/05	610	284	354	DCS800-S02-0680-04/05	680	282	354	25		950	1.76		D4
DCS800-S01-0740-04/05	740	344	429	DCS800-S02-0820-04/05	820	340	426	25	230; 1-ph ①	950	2.14		D4
DCS800-S01-0900-04/05	900	490	522	DCS800-S02-1000-04/05	1000	415	520	25		1900	2.66		D4
DCS800-S01-1190-04/05	1190 ③	553	690	DCS800-S02-1190-04/05	1190 ③	553	690	25 ②		600	5.00	●	D4+
DCS800-S01-1200-04/05	1200	558	696	DCS800-S02-1200-04/05	1200	498	624	25 ②		600	5.10	●	D5
DCS800-S01-1500-04/05	1500	698	870	DCS800-S02-1500-04/05	1500	623	780	25 ②	230; 1-ph	600	5.80	●	D5
DCS800-S01-2000-04/05	2000	930	1160	DCS800-S02-2000-04/05	2000	830	1040	25 ②		600	6.60	●	D5
DCS800-S01-2050-05	2050	953	1189	DCS800-S02-2050-05	2050	851	1066	-	400; 3-ph; 50 Hz	1600	8.00	●	D6
DCS800-S01-2500-04/05	2500	1163	1452	DCS800-S02-2500-04/05	2500	1038	1300	-	525; 3-ph; 50 Hz	1600	9.00	●	D6
DCS800-S01-3000-04/05	3000	1395	1740	DCS800-S02-3000-04/05	3000	1245	1560	-	460; 3-ph; 60 Hz	1600	11.10	●	D6
DCS800-S01-3300-04/05	3300	1535	1914	DCS800-S02-3300-04/05	3300	1370	1716	-		4200	11.70	●	D7
DCS800-S01-4000-04/05	4000	1860	2320	DCS800-S02-4000-04/05	4000	1660	2080	-	400; 3-ph; 50 Hz 460; 3-ph; 60 Hz	4200	13.00	●	D7
DCS800-S01-5200-04/05	5200	2418	3016	DCS800-S02-5200-04/05	5200	2158	2704	-		4200	19.00	●	D7
600 V / 690 V		600V	690V			600V	690V						
DCS800-S01-0290-06	290	203		DCS800-S02-0320-06	320	200		-	115/230; 1-ph	600	0.91	●	D3
DCS800-S01-0590-06	590	413		DCS800-S02-0650-06	650	405		-	230; 1-ph	950	1.86	●	D4
DCS800-S01-0900-06/07	900	630	720	DCS800-S02-0900-06/07	900	563	648	25 ②		600	5.10	●	D5
DCS800-S01-1500-06/07	1500	1050	1200	DCS800-S02-1500-06/07	1500	938	1080	25 ②	230; 1-ph	600	5.50	●	D5
DCS800-S01-2000-06/07	2000	1400	1600					25 ②		600	6.10	●	D5
DCS800-S01-2050-06/07	2050	1435	1640	DCS800-S02-2050-06/07	2050	1281	1476	-	400; 3-ph; 50 Hz	1600	9.20	●	D6
DCS800-S01-2500-06/07	2500	1750	2000	DCS800-S02-2500-06/07	2500	1563	1800	-	525; 3-ph; 60 Hz	1600	10.20	●	D6
DCS800-S01-3000-06/07	3000	2100	2400	DCS800-S02-3000-06/07	3000	1875	2160	-	460; 3-ph; 60 Hz	1600	12.20	●	D6
DCS800-S01-3300-06/07	3300	2310	2640	DCS800-S02-3300-06/07	3300	2063	2376	-		4200	13.10	●	D7
DCS800-S01-4000-06/07	4000	2800	3200	DCS800-S02-4000-06/07	4000	2500	2880	-	400; 3-ph; 50 Hz 460; 3-ph; 60 Hz	4200	15.10	●	D7
DCS800-S01-4800-06/07	4800	3360	3840	DCS800-S02-4800-06/07	4800	3000	3456	-		4200	19.50	●	D7
800 V		690V				800V							
DCS800-S01-1930-08	1900	1739		DCS800-S02-1930-08	1900	1558		-	460; 3-ph; 50 Hz	1600	9.00	●	D6
DCS800-S01-2500-08	2500	2268		DCS800-S02-2500-08	2500	2050		-	525; 3-ph; 50 Hz	1600	10.70	●	D6
DCS800-S01-3000-08	3000	2745		DCS800-S02-3000-08	3000	2460		-	460; 3-ph; 60 Hz	1600	12.70	●	D6
DCS800-S01-3300-08	3300	3020		DCS800-S02-3300-08	3300	2706		-		4200	13.40	●	D7
DCS800-S01-4000-08	4000	3660		DCS800-S02-4000-08	4000	3280		-	400; 3-ph; 50 Hz 460; 3-ph; 60 Hz	4200	15.60	●	D7
DCS800-S01-4800-08	4800	4392		DCS800-S02-4800-08	4800	3936		-		4200	20.00	●	D7
990 V		990V				990V							
DCS800-S01-2050-10	2050	2878		DCS800-S02-2050-09	2050	2132		-		4200	9.70	●	D7
DCS800-S01-2600-10	2600	3016		DCS800-S02-2600-09	2600	2704		-	400; 3-ph; 50 Hz	4200	12.10	●	D7
DCS800-S01-3300-10	3300	3828		DCS800-S02-3300-09	3300	3432		-	460; 3-ph; 60 Hz	4200	15.60	●	D7
DCS800-S01-4000-10	4000	4640		DCS800-S02-4000-09	4000	4160		-		4200	20.20	●	D7
1200 V	Data on request												

Continued…

Question 2

A pump uses a three-phase induction motor driven by a variable speed drive with V/f control. V/f ratio is maintained up to 50 Hz. The motor name plate are shown below.



a) State the rated speed and rated current if supply voltage is 400 V, 50 Hz.

[4 marks]

b) Sketch the motor terminal and show the connection of the supply cables to the motor terminals.

[4 marks]

c) Calculate the rated motor torque

[2 marks]

d) Calculate the voltage when motor runs at 35 Hz and deliver rated motor torque. The motor parameters are given below.

$$R_s = 1.4\,\Omega\,,\ R_r' = 1.3\,\Omega\,, X_s = 2.5\,\Omega,\ X_r' = 3.0\,\Omega$$

Given torque equation as:

$$T = \frac{3}{\omega_{ms}}\left[\frac{V^2 R_r'/s}{\left(R_s + \frac{R_r'}{s}\right)^2 + (X_s + X_r')^2}\right]$$

[11 marks]

e) It is found that when voltage computed in (d) is supplied to the motor, the motor produces torque lower than rated value. Explain the reason for the drop in torque production.

[4 marks]

Continued...

Question 3

Six dust collectors are connected to one exhaust fan shown in Figures Q3a and Q3b. The exhaust fan is driven by a 3-phase induction motor. A star-delta starter is used for the motor. The motor has been operating for 11 years.

Motor Name plate information

37kW, 415V, 66.6 A, 4 pole, 1465 rpm, efficiency 91%, IE1.

Electrical Paramaters measured at the start delta starter when motor runs.

400V, 60A, pf 0.83

Damper is used to control the flow rate.

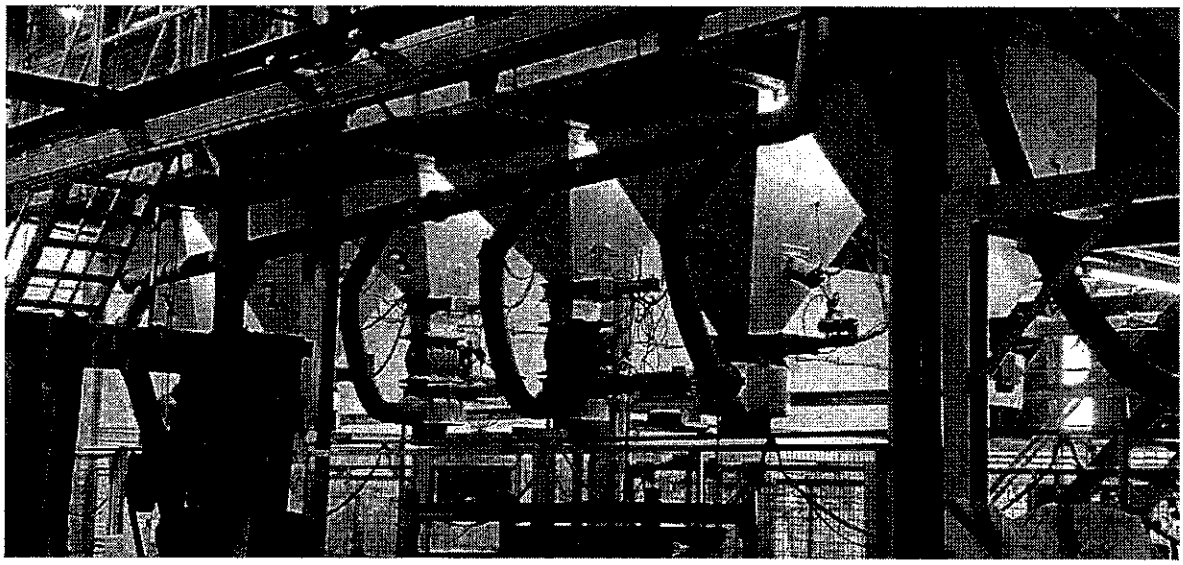


Figure Q3a : Dust Collector System

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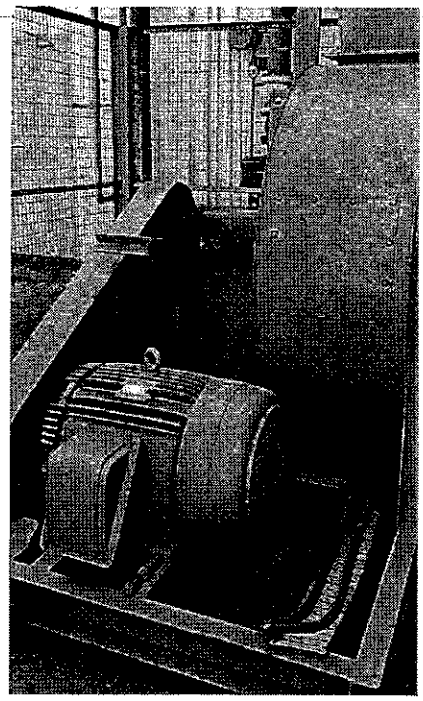


Figure Q3b: Exhaust Fan Motor

a) Calculate the total electrical power consumed by the existing exhaust system.

[3 marks]

b) In order to save energy, a variable speed drive is selected to reduce speed of the exhaust fan. Select a suitable variable speed drives for this application. Refer to Table Q3a.

[3 marks]

c) Would you recommend to replace the existing IE1 motor to IE2 or IE3 motor to further save in energy usage. State your reason/s.

[5 marks]

d) Calculate power and energy per month by the motor system when it now operates at 40 Hz. Assumed the system drives full load. The exhaust fan runs for 14 hours/day, 20 days/month.

[6 marks]

e) Explain referring to the Affinity law, how do the exhaust fan consume lesser power when speed is reduced.

[4 marks]

f) The motor is placed at the outdoor, do you think there is going to be any heating issue at the motor when motor speed is reduced compared to when it runs with star-delta starter.

[4 marks]

Continued...

Table Q3a : Selection Table for Variable Speed Drives

References (continued)

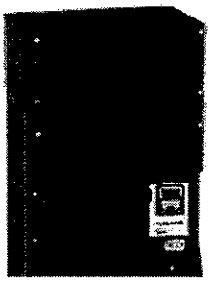
Variable speed drives

Altivar 61

Supply voltage 380...480 V 50/60 Hz

ATV 61HU22N4

ATV 61HU40N4Z



IP 20 drives

Motor		Line supply				Altivar 61				
Power indicated on rating plate (1)		Line current (2)		Apparent power	Maximum prospective line Isc	Maximum continuous current (1)		Max. transient current for 60 s	Reference	Weight
		380 V	480 V	380 V		380 V (IEC)	460 V (NEC)			
kW	HP	A	A	kVA	kA	A		A		kg
Three-phase supply voltage: 380...480 V 50/60 Hz										
0.75	1	3.7	3	2.4	5	2.3	2.1	2.7	ATV 61H075N4	3.000
1.5	2	5.8	5.3	3.8	5	4.1	3.4	4.9	ATV 61HU15N4	3.000
2.2	3	8.2	7.1	5.4	5	5.8	4.8	6.9	ATV 61HU22N4	3.000
3	–	10.7	9	7	5	7.8	6.2	9.3	ATV 61HU30N4	4.000
4	5	14.1	11.5	9.3	5	10.5	7.6	12.6	ATV 61HU40N4	4.000
5.5	7.5	20.3	17	13.4	22	14.3	11	17.1	ATV 61HU55N4	5.500
7.5	10	27	22.2	17.8	22	17.6	14	21.1	ATV 61HU75N4	5.500
11	15	36.6	30	24.1	22	27.7	21	33.2	ATV 61HD11N4	7.000
15	20	48	39	31.6	22	33	27	39.6	ATV 61HD15N4	22.000
18.5	25	45.5	37.5	29.9	22	41	34	49.2	ATV 61HD18N4	22.000
22	30	50	42	32.9	22	46	40	57.6	ATV 61HD22N4	30.000
30	40	66	56	43.4	22	66	52	79.2	ATV 61HD30N4	37.000
37	50	84	69	55.3	22	79	65	94.8	ATV 61HD37N4	37.000
45	60	104	85	68.5	22	94	77	112.8	ATV 61HD45N4	44.000
55	75	120	101	79	22	116	96	139.2	ATV 61HD55N4	44.000
75	100	167	137	109.9	22	160	124	192	ATV 61HD75N4	44.000
90	125	166	143	109.3	35	179	179	214.8	ATV 61HD90N4	64.000
110	150	202	168	133	35	215	215	258	ATV 61HC11N4	64.000
132	200	239	224	157.3	35	259	259	310.8	ATV 61HC13N4	106.000
160	250	289	275	190.2	50	314	314	376.8	ATV 61HC16N4	116.000
200	300	357	331	235	50	427	427	512.4	ATV 61HC22N4	163.000
220	350	396	383	260.6	50					
250	400	444	435	292.2	50	481	481	577.2	ATV 61HC25N4	207.000
280	450	494	494	325.1	50	616	616	739.2	ATV 61HC31N4	207.000
315	500	555	544	365.3	50					
355	–	637	597	419.3	50	759	759	910.8	ATV 61HC40N4	320.000
400	600	709	644	466.6	50					
500	700	876	760	576.6	50	941	941	1129.2	ATV 61HC50N4	330.000
560	800	978	856	643.6	50	1188	1188	1425.6	ATV 61HC63N4	435.000
630	900	1091	964	718	50					

Continued...

Question 4

a) State four advantages of Permanent Magnet Synchronous Motor (PMSM) for electric vehicles.

[4 marks]

b) Figure Q4 shows the Vector Controlled PMSM-Drive Operation in an Electric Vehicle. Explain the operation of the drive in the electric vehicle especially for speed control.

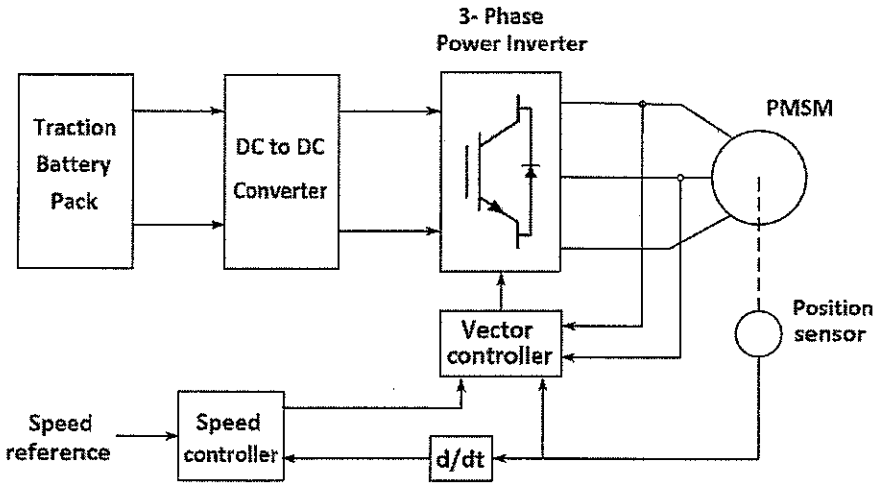


Figure Q4

[4 marks]

c) Explain two types of PMSM with sketching of rotors.

[6 marks]

d) Explain with a sketch the working principle of a switched reluctance motor.

[6 marks]

e) State two advantages and disadvantages of a variable reluctance stepper motor.

[5 marks]

End of Paper